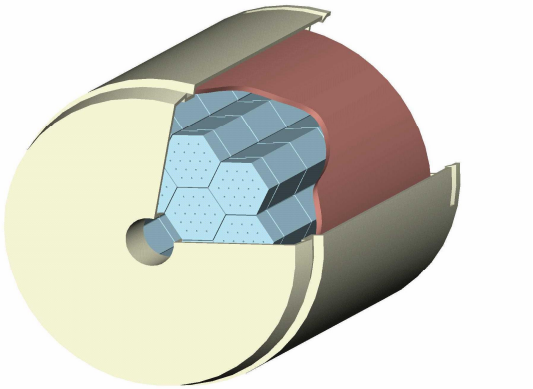
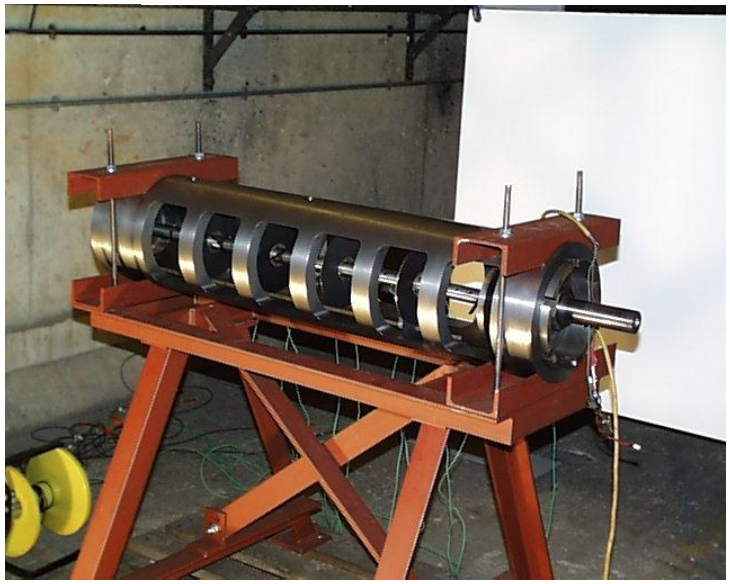


Two-dimensional modelling of modular charge gun firings

Clive Woodley, Steve Fuller

A presentation to: 24th International Symposium on Ballistics



September 2008

QinetiQ

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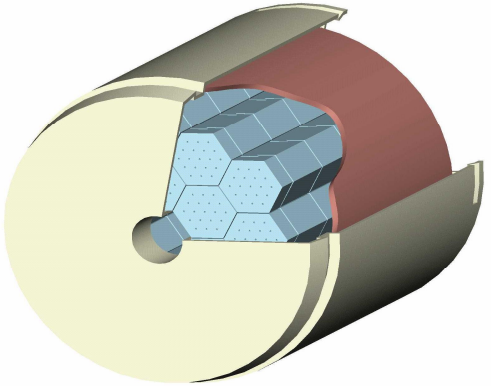
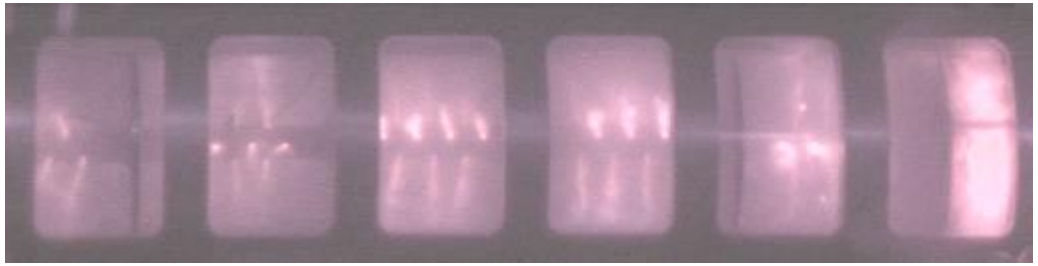
01 Description of UPCS2

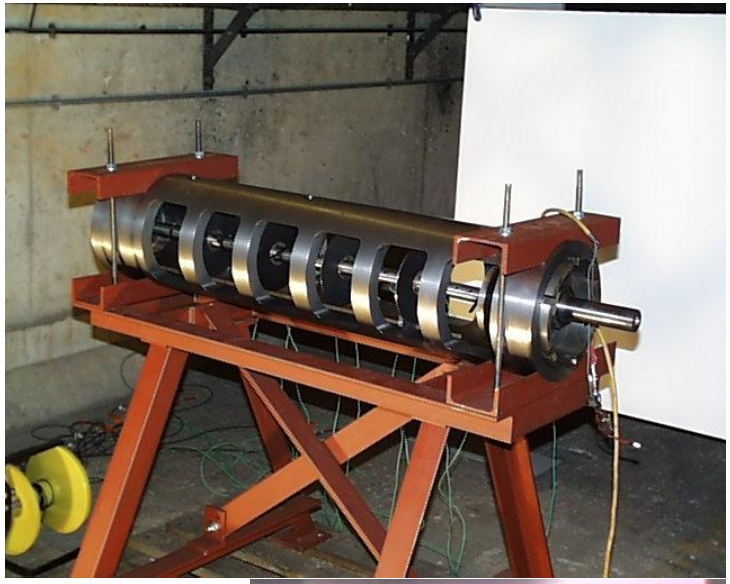
02 Description of QIMIBS

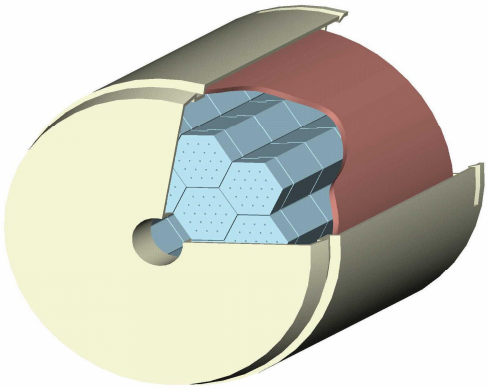
03 IB modelling of UPCS2





01
Description of UPCS2





cs?

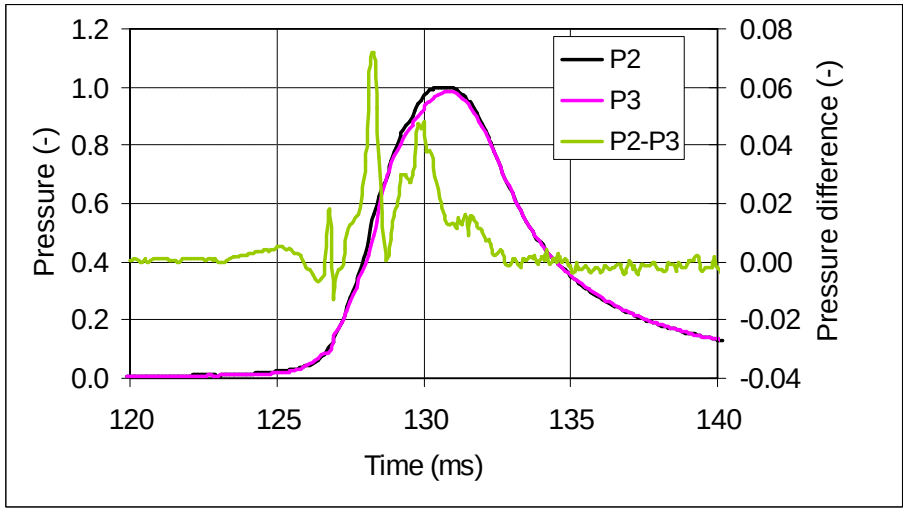
Existing 155mm charge inventory replaced with 1 module

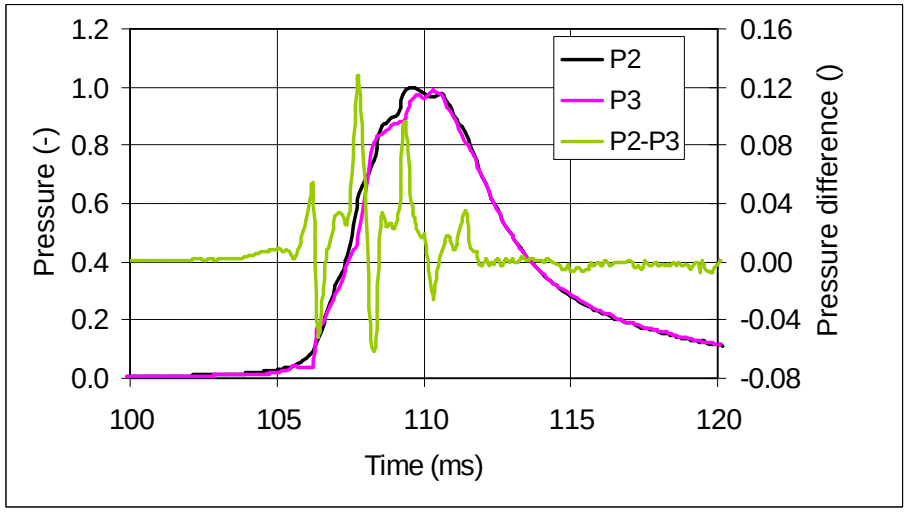
bjectives

- To determine temperature coefficient data for experimental propellant under gun firing conditions
- To determine top zone performance for experimental propellant
- To determine low zone performance for experimental propellant
- **To investigate the performance of the ignition system**

some results

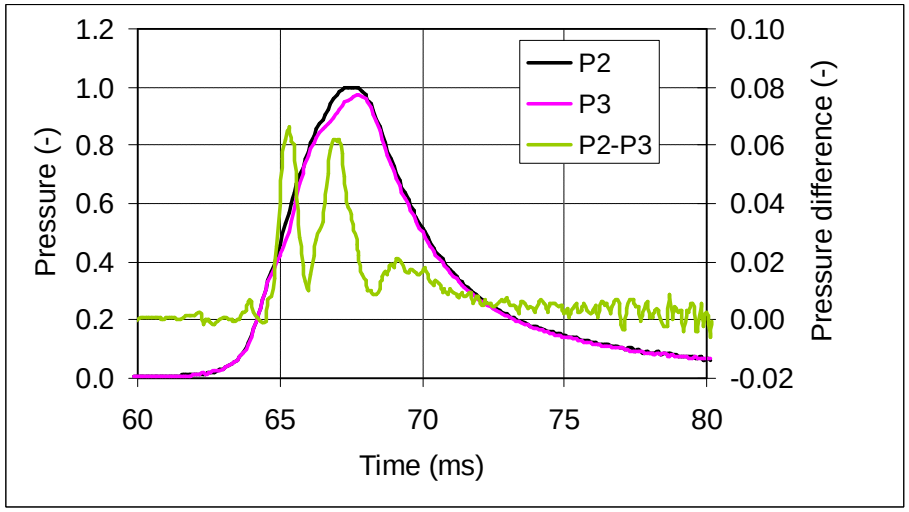
- Smooth pressure-time profiles were recorded for Z2 and Z3 charges.
- A smooth pressure time profile at zone 4 (+21^{0}C) was also observed
- But so was a ónot so smooth curveô

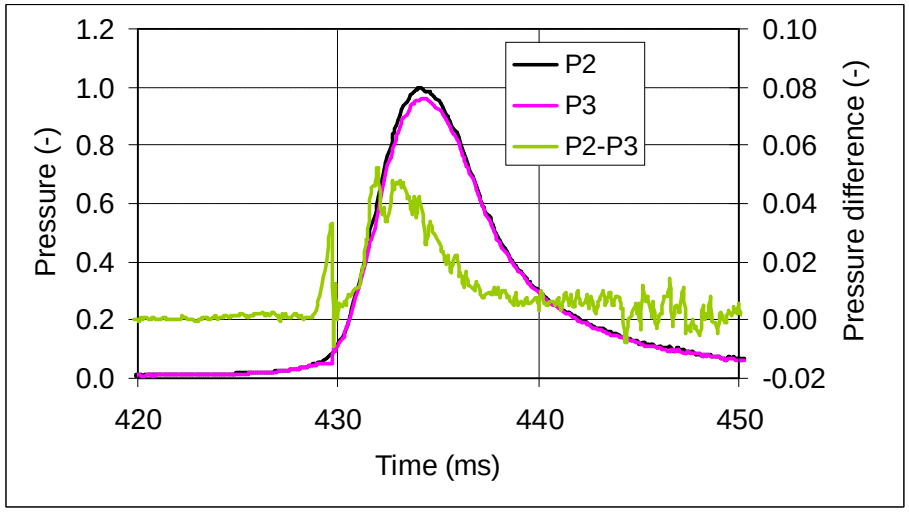




some results

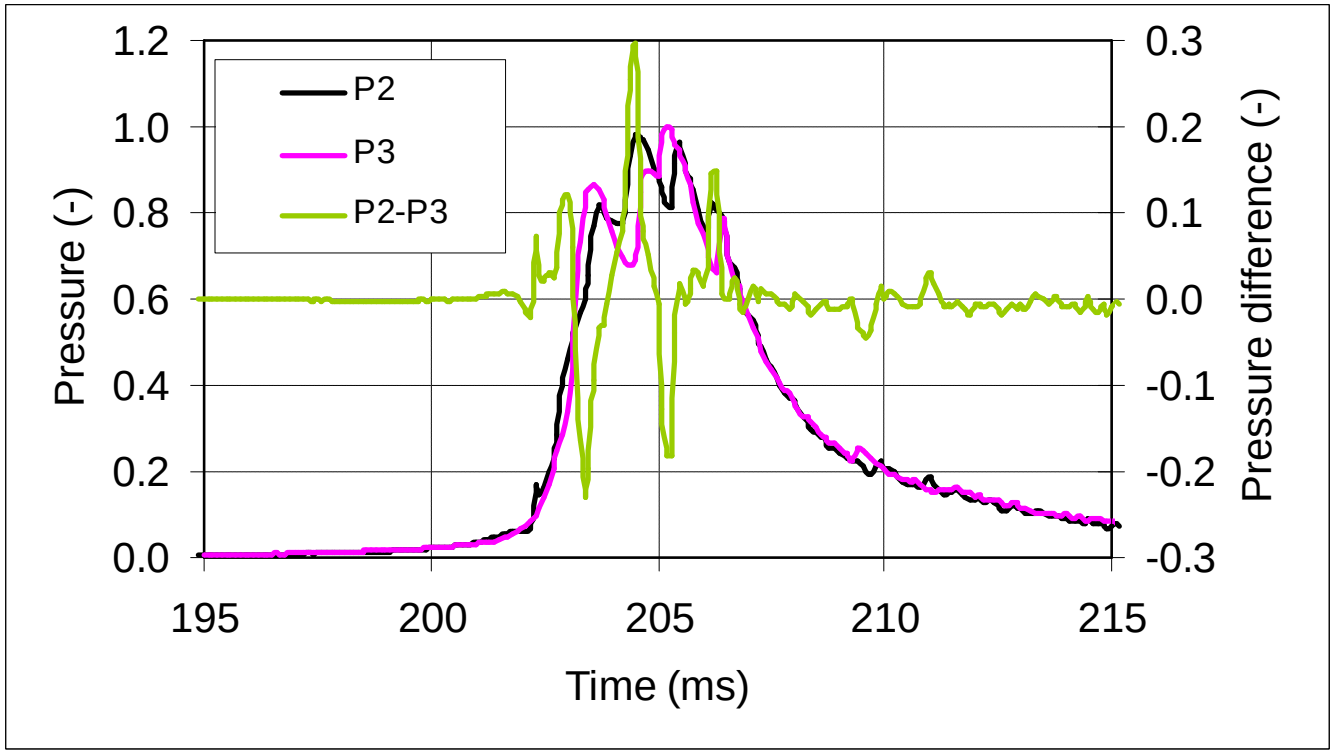
- Results at zone 4 at 63^{0}C and -33^{0}C were acceptable





some results

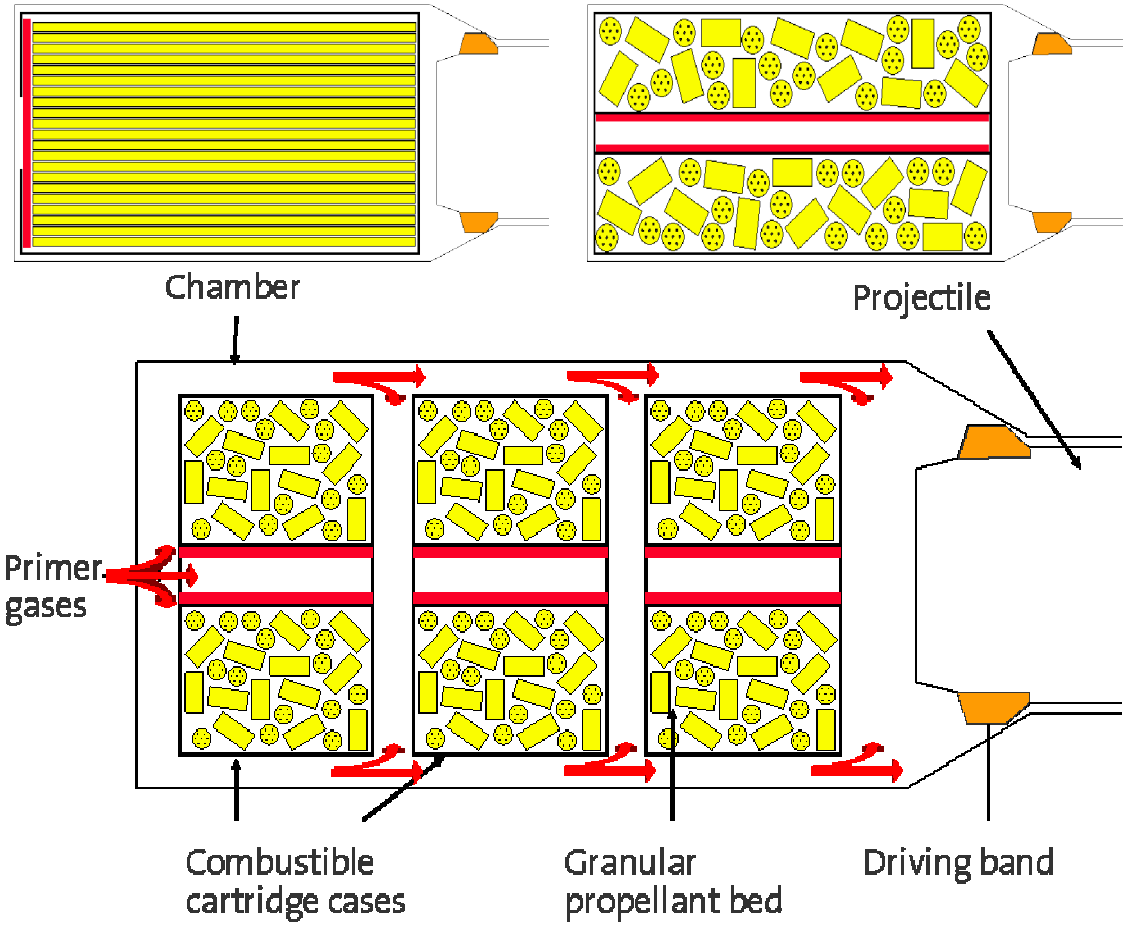
- 4.5 modules at -33C gave bad results!
- The firing mechanism was forcibly ejected from the gun breech with a substantial velocity



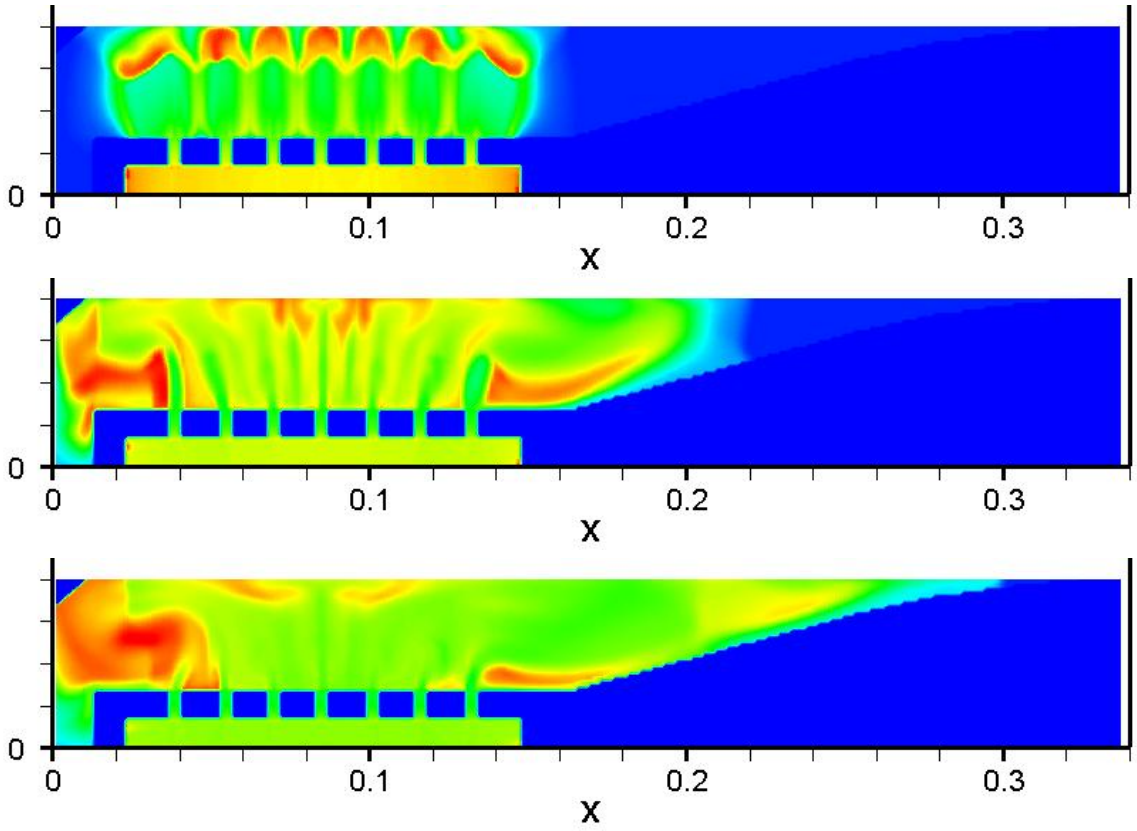
cs background

Safety & performance are important requirements ï linked to ignition

- More conventional charges, comprising stick and granular propellant, can be modelled
- Want any pressure waves to be eliminated or minimised and consistent
- Want simultaneous ignition along length of charge
- Combustible cartridge cases present barrier to flamespread along the propellant bed
- Modules act as projectiles!



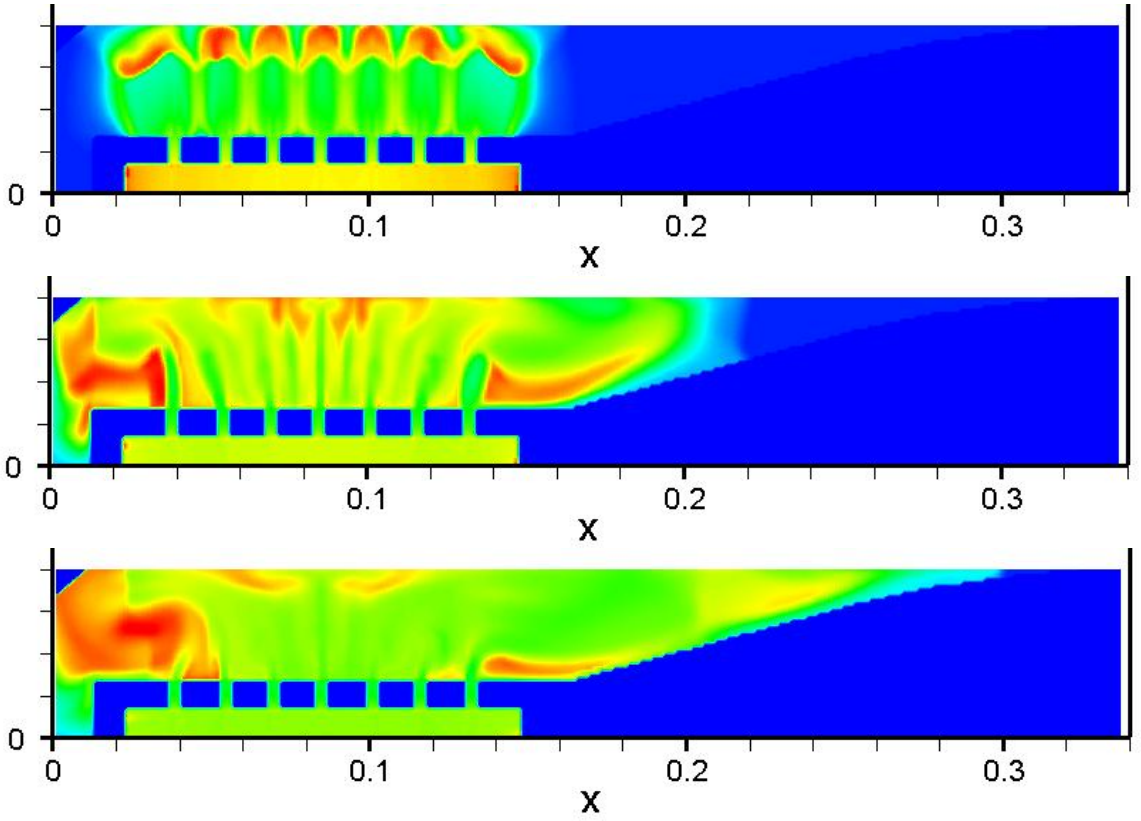
02
Description of QIMIBS



kground

2D mortar code

- Developed initially with MOD funding
- Developed further using QinetiQ funding
- Details presented at 22nd International Symposium on Ballistics
- Ability to represent internal solid boundaries and burst discs
- Modified for CTA, MCS & other applications



ase flow equations

$$\frac{\partial}{\partial t}(\rho\varepsilon) + \frac{\partial}{\partial z}(\rho\varepsilon u) + \frac{\partial}{\partial r}(\rho\varepsilon v) = -\frac{\varepsilon\rho v}{r} + \dot{m}_{ig} + \sum_{k=1}^{n} \dot{m}^k$$

$$\frac{\partial}{\partial t}(\rho\varepsilon u) + \frac{\partial}{\partial z}[\varepsilon(\rho u^2 + p)] + \frac{\partial}{\partial r}(\rho\varepsilon uv) = -\frac{\varepsilon\rho uv}{r} + p\frac{\partial\varepsilon}{\partial z} + \sum_{k=1}^{n}(\dot{m}^k u^k - f_z^k)$$

$$\frac{\partial}{\partial t}(\rho\varepsilon v) + \frac{\partial}{\partial z}(\varepsilon\rho uv) + \frac{\partial}{\partial r}[\varepsilon(\rho v^2 + p)] = -\frac{\varepsilon\rho v^2}{r} + p\frac{\partial\varepsilon}{\partial r} + \sum_{k=1}^{n}(\dot{m}^k v^k - f_r^k)$$

$$\frac{\partial}{\partial t}(\rho\varepsilon E) + \frac{\partial}{\partial z}[\varepsilon\rho u(E + p/\rho)] + \frac{\partial}{\partial r}[\rho\varepsilon v(E + p/\rho)] = -\frac{\varepsilon\rho v}{r}(E + p/\rho) + \dot{m}_{ig}Q_{ig}$$

$$-W + E_E + \sum_{k=1}^{n}[\dot{m}^k(Q_p^k + \kappa^k) - p\left(\frac{\partial(\varepsilon^k u^k)}{\partial z} + \frac{\partial(\varepsilon^k v^k)}{\partial r}\right) - u^k f_z^k - v^k f_r^k - q^k N^k S^k]$$

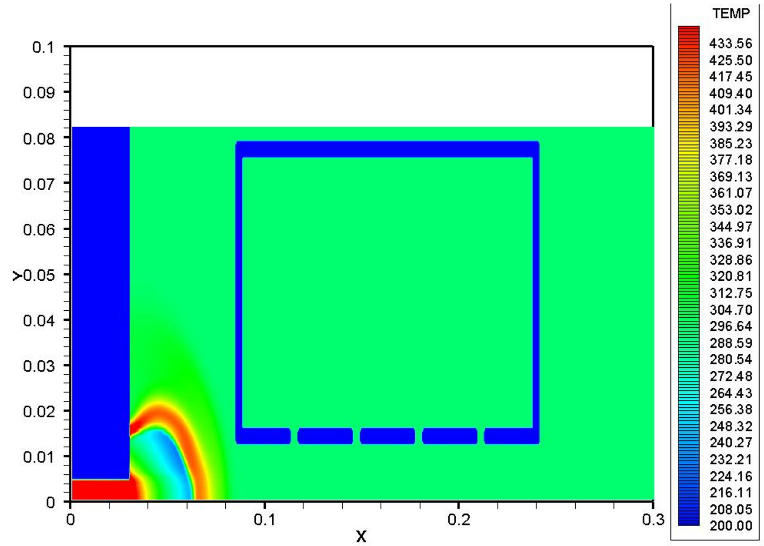
$$\frac{\partial}{\partial t}(\rho^k\varepsilon^k) + \frac{\partial}{\partial z}(\rho^k\varepsilon^k u^k) + \frac{\partial}{\partial r}(\rho^k\varepsilon^k v^k) = -\dot{m}^k - \frac{\varepsilon^k\rho^k u^k}{r}$$

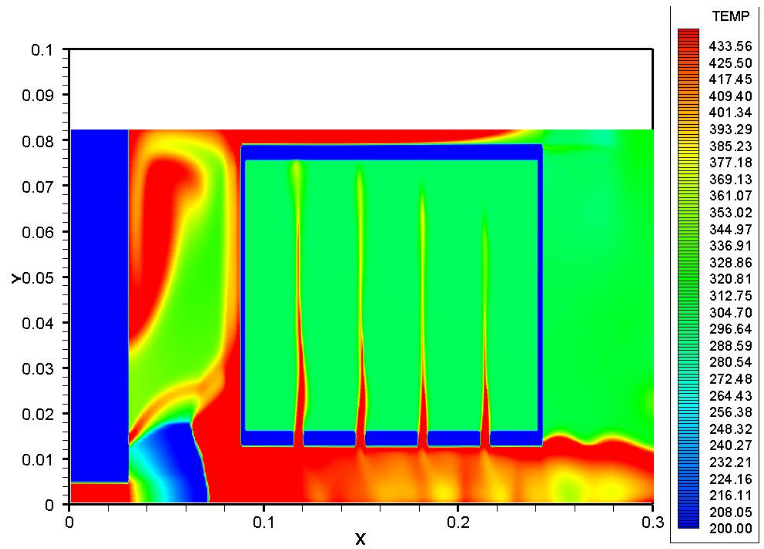
$$\frac{\partial}{\partial t}(\rho^k\varepsilon^k u^k) + \frac{\partial}{\partial z}[\varepsilon^k(\rho^k(u^k)^2 + p + p_{is}^k)] + \frac{\partial}{\partial r}(\rho^k\varepsilon^k u^k v^k) = p\frac{\partial\varepsilon^k}{\partial z} - \frac{\varepsilon^k\rho^k u^k v^k}{r} - \dot{m}^k u^k + f_z^k$$

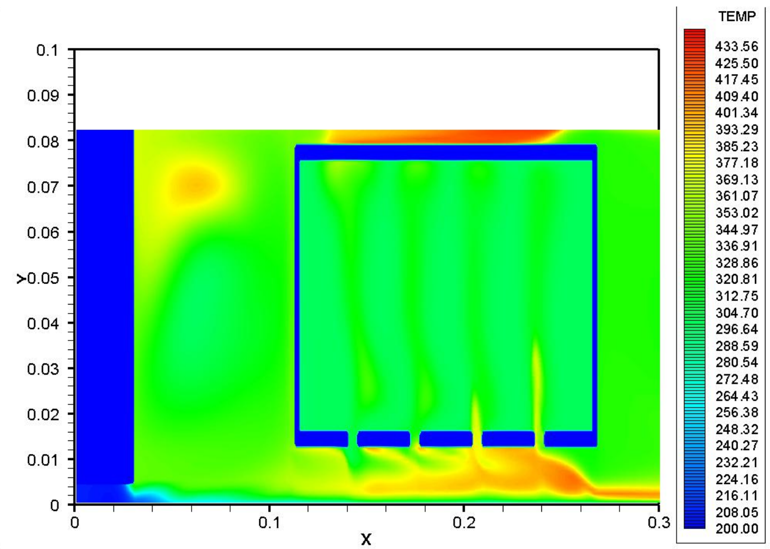
$$\frac{\partial}{\partial t}(\rho^k\varepsilon^k v^k) + \frac{\partial}{\partial z}(\varepsilon^k\rho^k u^k v^k) + \frac{\partial}{\partial r}[\varepsilon^k(\rho^k(v^k)^2 + p + p_{is}^k) = p\frac{\partial\varepsilon^k}{\partial r} - \frac{\varepsilon^k\rho^k(v^k)^2}{r} - \dot{m}^k v^k + f_r^k$$

$$\frac{\partial}{\partial t}(N^k) + \frac{\partial}{\partial z}(N^k u^k) + \frac{\partial}{\partial r}(N^k v^k) = -\frac{v^k N^k}{r}$$

03
IB Modelling of UPCS2







modelling strategy

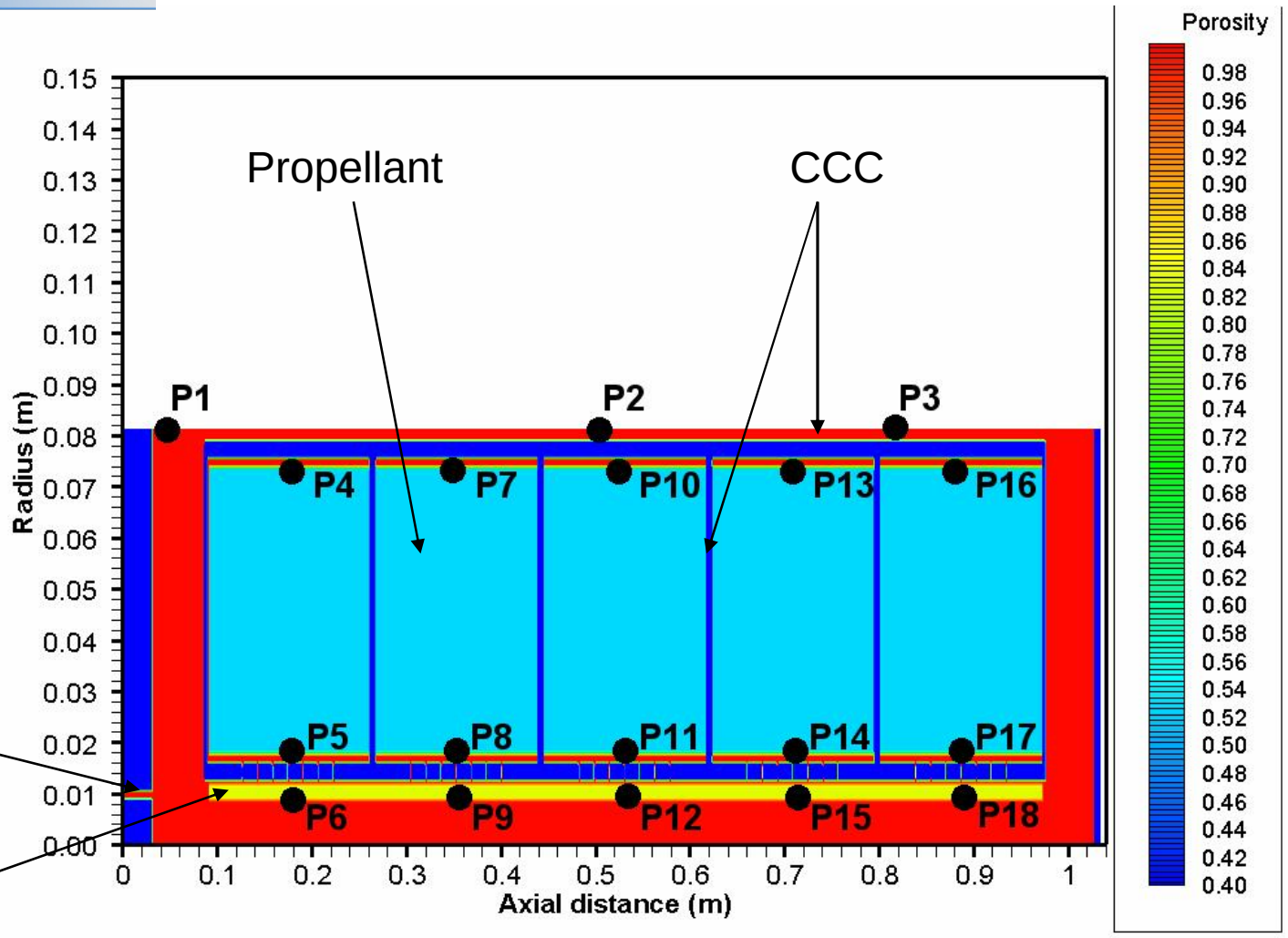
- No single code available that can model all details
- Various ignition scenarios were investigated using QIMIBS
  - Prediction of ignition time for each module
  - Ignition at breech
  - Ignition at projectile
  - Ignition at mid-chamber
- Estimated ignition delays were input to QIBS (1D code)
  - Predicted pressure profiles compared with experiment
- Ignition at breech and mid-chamber did not produce pressure profiles of desired shape
- Most likely ignition scenario was ignition adjacent to projectile

nitial geometry for modelling

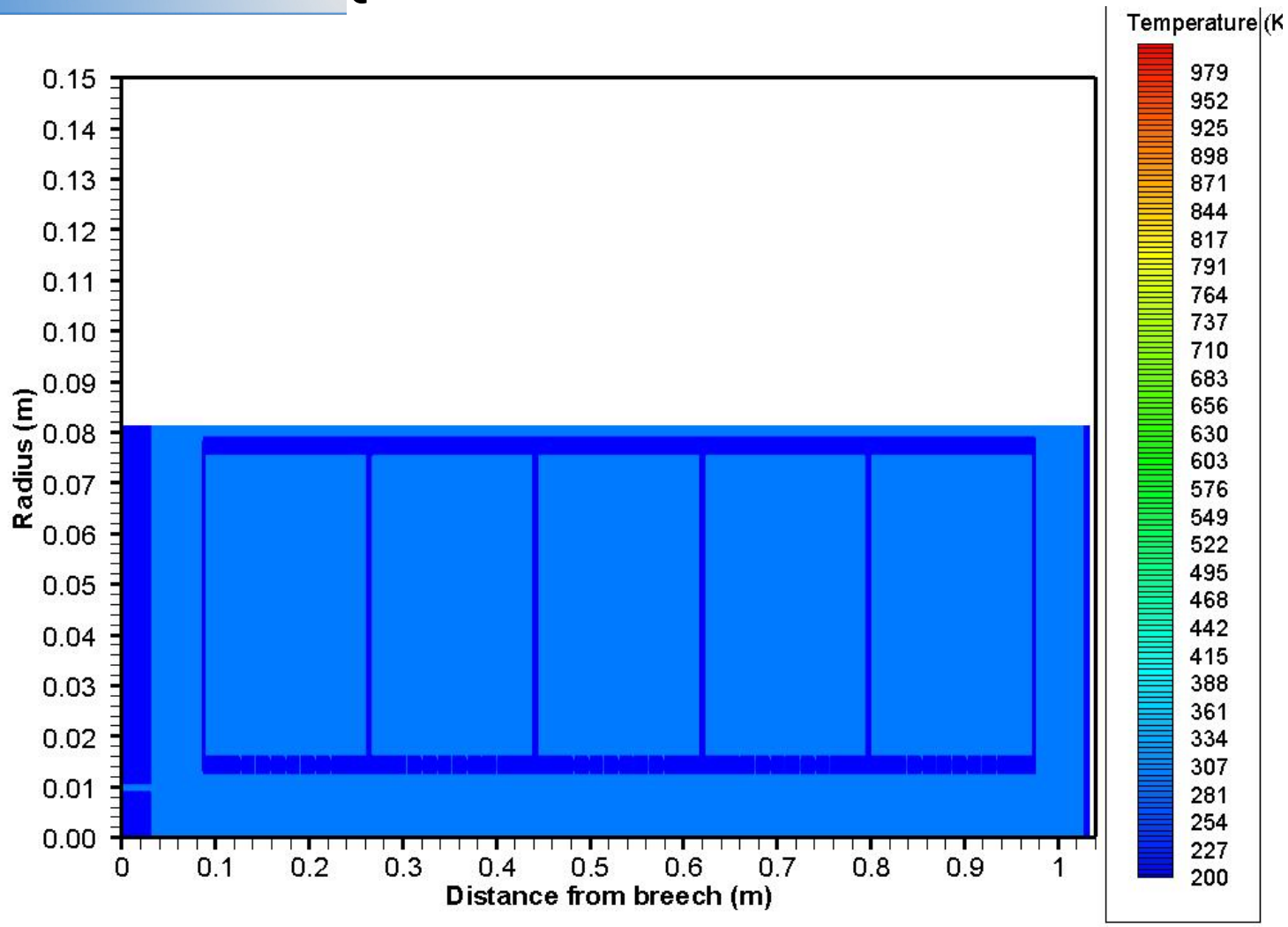
P1-P18 are fictitious pressure gauges

Primer

Igniter

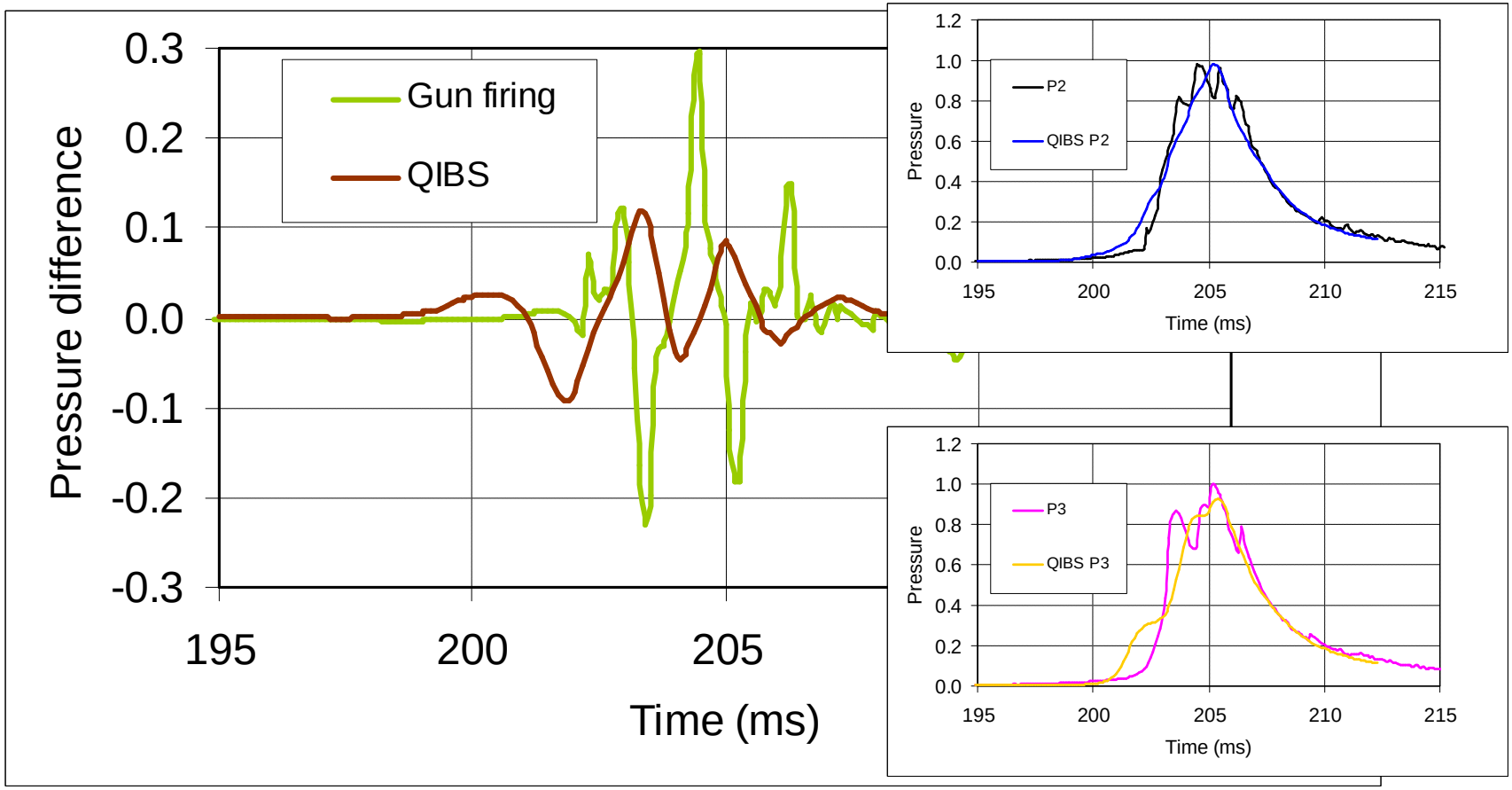


QIMIBS simulation



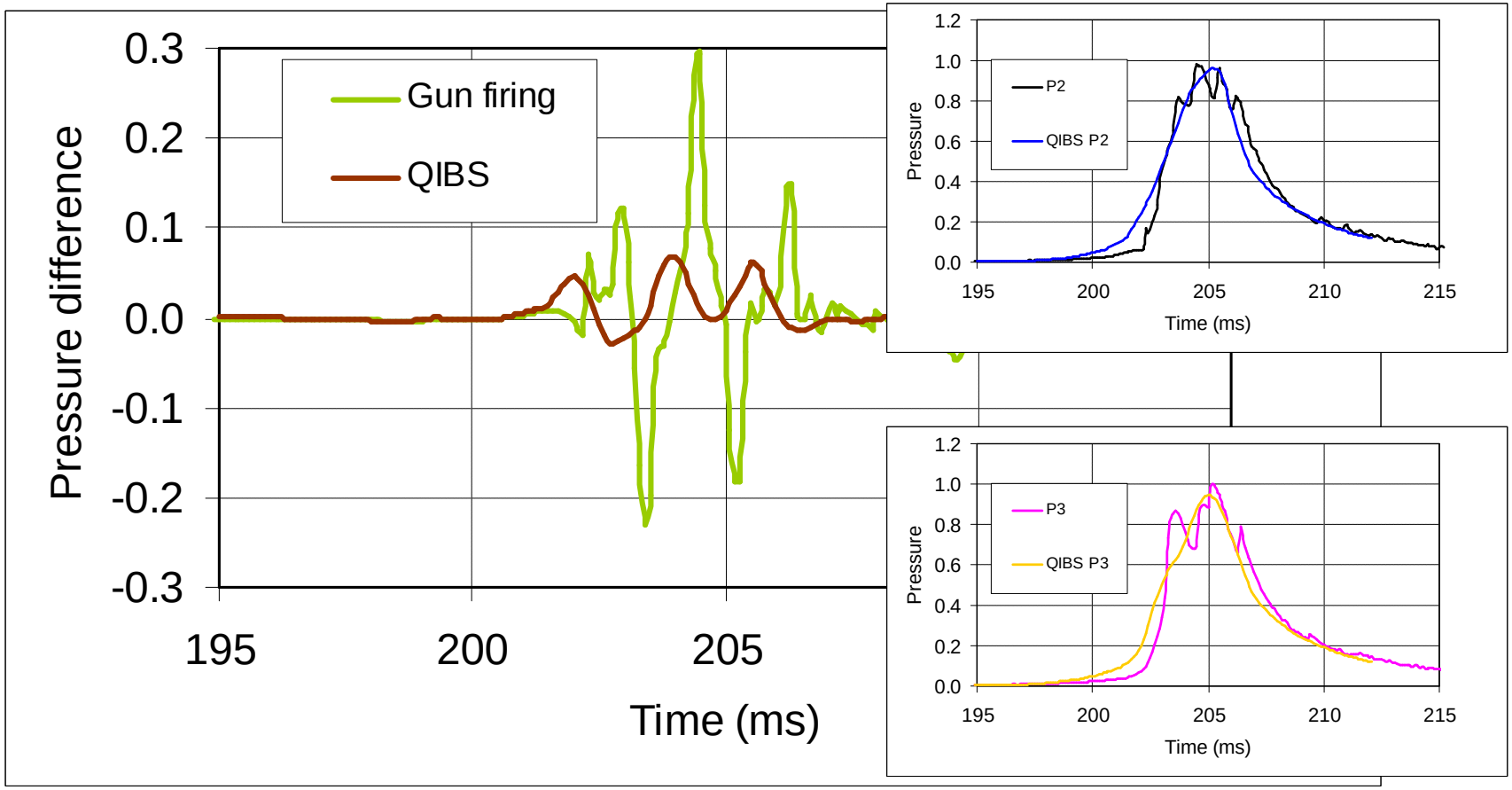
example ï breech ignition

- Predicted and measured pressure differences are out of phase



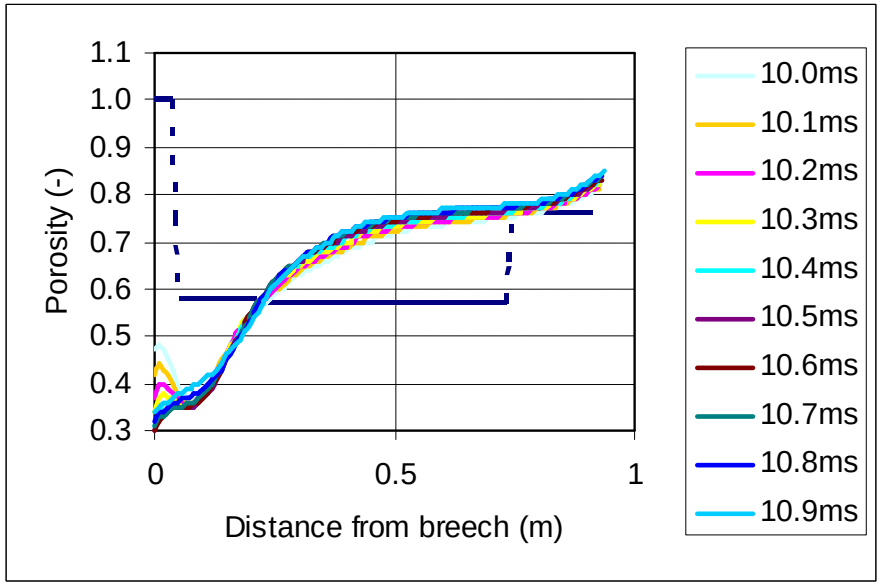
example ï ignition at projectile

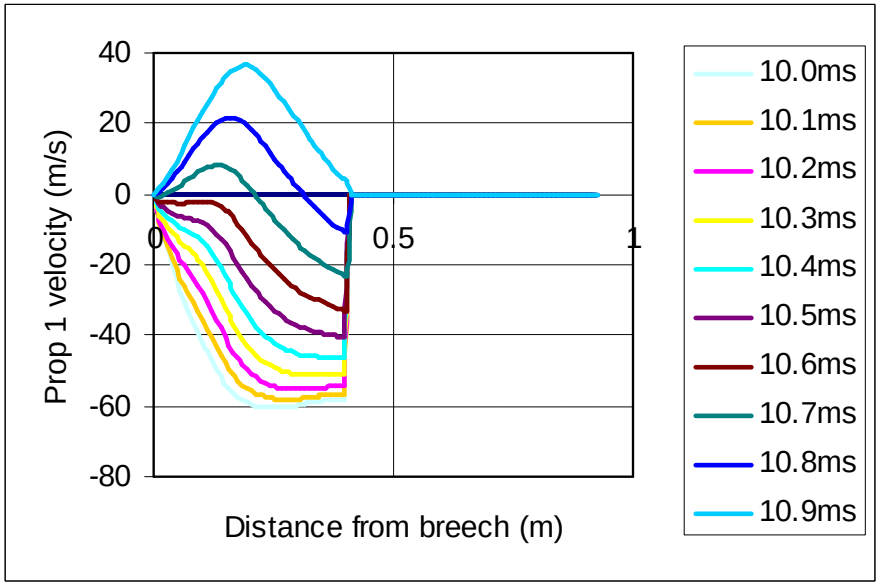
- Predicted and measured pressure differences are slightly out of phase



gnition at projectile

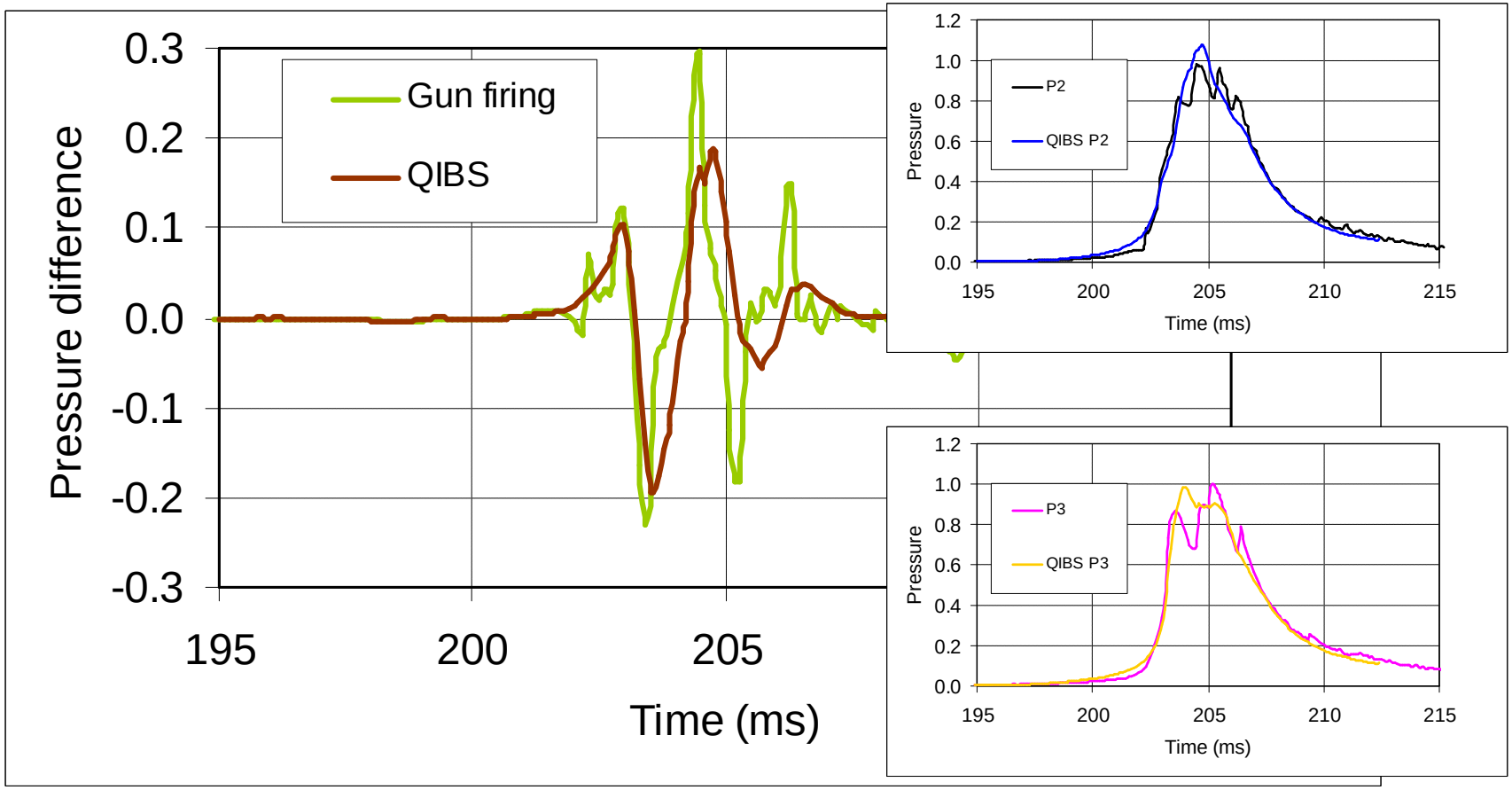
- Analysis of QIBS simulation showed
  - Compression of propellant bed for module 1 propellant at breech
  - Significant rearward propellant velocity
  - Propellant shatter likely





gnition at projectile ï final simulation

- Excellent agreement up to maximum pressure



- The quantity of gun powder in the flash tubes was marginal for simultaneous ignition
- The charge appears to have been ignited at the projectile end with the modules closer to the breech then being subsequently ignited in turn
- Ignition at the projectile end then drove the charge towards the breech at over 100 mph and caused shatter of propellant in the module nearest to the breech
- The ensuing pressure wave drove the charge back towards the projectile at over 200 mph and shattered yet more propellant
- Subsequent simulations indicate that gun powder should also be present on the outside of the flash tube (in contact with the propellant) to improve the ignition train
- Future work - better representation of CCC to allow simulation of full IB cycle

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